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Use of web-based simulators and YouTube for teaching of Magnetic Resonance Imaging

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ABSTRACT

Interactive web-based software for teaching of 3D vector dynamics involved in Magnetic Resonance Imaging (MRI) was developed. The software is briefly discussed along with the background, design, implementation, dissemination and educational value.

INTRODUCTION

Magnetic Resonance Imaging (MRI) is an important part of the biomedical engineering curriculum (Wilhjelm 2011). It is challenging, however, to give students an intuitive understanding of the basic magnetic resonance phenomenon and the many MRI techniques. Compact mathematical descriptions of MRI can be made, but students are typically left with little intuitive understanding unless the reality expressed in the math is in focus. The relevant nuclear vector dynamics happen in four dimensions, and are therefore not well suited for illustration on blackboard. 3D movies are more appropriate, but do not encourage active learning. The typical solution employed by educators is hand waving (literally), since arm motions may be used to illustrate vector dynamics. Students find this confusing and they are left in bad positions, if the meaning is not grasped during lectures.

Educational software was therefore developed over the last years. The *JavaCompass (*Hanson 2011b) is aimed at day 1 of MRI education, and demonstrates the basic magnetic resonance phenomenon in a way understandable to almost anybody. The more advanced *Bloch Simulator (*Hanson 2007) aims much further. Both are freely available and can be run directly from the software homepages http://www.drcmr.dk/JavaCompass and http://www.drcmr.dk/bloch that also links to YouTube videos (trademark Google Inc, USA). The software is mainly aimed at educators for interactive demonstration of MRI techniques during lectures, but is also suited for student exercises which can improve the understanding of MRI concepts. Example software with similar focus or potential is *SpinPlayer* (Benoit-Cattin, 2005) and educational tools by P.G. Björklund (Björklund, 2011).

Though the developed software and teaching material is directly targeted at MRI, other areas of engineering and physics education are confronted with similar challenges. The experience gained during software design, implementation, application and dissemination may thus be of interest in a broader context. These are the topics of the presentation as well as the extent to which active learning based on the software may improve student understanding.

The empirical data are limited, and consist of general course evaluations, and data collected in a study conducted in 2011 (Hanson 2012) to evaluate the impact of the Bloch simulator in the DTU course "Medical Magnetic Resonance Imaging" (DTU study handbook 2011): An interactive teaching session on advanced topics (RF pulse types, the Fourier relationship, selectivity) was evaluated using pre- and post-lecture anonymous questionnaires. These subjects are challenging and significant, and it was hypothesized that the approach may improve student understanding considerably. Though rigorous testing of the benefit over traditional teaching was not within the scope of the study, indications of improved skills were found, and the student satisfaction was good.

DISCUSSION

Each of the mentioned topics of the presentation is briefly reviewed:

- Software design: The graphical, interactive software is made for MRI educators for use during lectures, and for students to use during exercises and personal studies. Flexibility is to a large extent traded off for simplicity. The *JavaCompass* is designed for day 1 of MRI education whereas the *Bloch simulator* visualizes spin dynamics in user-determined magnetic fields varying in time and space as during MRI.
- Software implementation: The original implementation of the *Bloch simulator* (Hanson 2007) was made partly in proprietary software (IDL, Research Systems Inc), partly in Perl (both are programming languages). This version could be distributed and executed freely but installation was cumbersome. A port to Flex/ActionScript (trademark Adobe) was made by the gaming company Oddlabs with support from *the Danish Ministry of Science, Technology and Innovation*. The resulting software executes in all major browsers on the vast majority of personal computers (>95%) with no need for installation of additional software. The *JavaCompass* is programmed in Java (trademark Oracle) with similar properties (~75% penetration).
- Dissemination: Brief written documentation is available in a published paper (Hanson 2007), on the web, and in the program itself. The use is better illustrated, however, in a series of 5 short YouTube videos which present basic software uses and serve as appetizers. In total, these are seen more than 100 times daily (36000 in total, October 2012), and feedback is positive. Students are encouraged to see the videos early in courses to better understand demonstrations done interactively during classes and to learn the use of the simulator. Demonstrations done later in the education are not documented in videos, but the students are in principle able to replicate them on their own. Also, they may test own ideas and understanding.
- A single study (Hanson 2012) has been addressing the benefit of using the software for teaching of interactions between nuclear spin and radio waves during MRI (RF interactions). A brief traditional introduction to the subject was given in the course "31547 Medical Magnetic Resonance Imaging" (DTU study handbook 2011). A questionnaire on the student's experience with the simulator, and on RF interactions, was presented to the students the following week unannounced. It was answered anonymously and was followed immediately by a lecture including group work with questions relevant to the subject ("How can this and that effect be explored using the simulator?"). Answers were discussed in class, and were tried out. The questionnaire was repeated the following week unannounced (slightly modified) to check if the understanding had increased, if the gain correlated with simulator use in the meantime, and if the student satisfaction was acceptable. Ahead of the simulator exercise, most students found the simulations during lectures beneficial, but some reported problems using the simulator independently (YouTube videos released in the meantime, may have helped). Some increase in the understanding of magnetic field interactions was seen between the two repetitions of the questionnaire, but no students had used the simulator independently in the meantime (only in the plenary lecture). The student satisfaction with the exercise was high, but the observed gains could not be uniquely attributed to use of the simulator .

Based on student evaluations, and comments at YouTube and from peers, the simulators are advantageous in the context of MRI education. The easy access, and the documentation at YouTube is deemed important in this context. The benefit to students has not been quantified though results of the single controlled study performed were consistent with a gain. It is positive that students consistently rated the satisfaction with simulations high in anonymous course evaluations and in the more targeted questionnaire. Simulator use also makes the experience for the lecturer much more satisfactory since it helps conveying the necessary understanding of MRI methods.

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